Phonon anomaly in Bi$_2$Sr$_2$CaCu$_2$O$_{8+\delta}$*  
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— Electron-phonon coupling (EPC) plays in many exotic phenomena displayed by strongly-correlated electron materials, such as the pairing mechanism in high-$T_C$ superconductors and metal-insulator transition in ruthenates. Many studies show a strong renormalization of quasi-particle band structure near Fermi energy associated with the coupling to boson modes $\sim$40-50 meV. However, there is no clear picture of the origin of these modes. With angle-resolved electron energy loss spectroscopy, we have studied the lattice dynamics of Bi$_2$Sr$_2$CaCu$_2$O$_{8+\delta}$ surface. The data indicate a phonon anomaly of modes $\sim$50 meV, identified as the in-plane Cu-O stretching modes, where the energy shifts (softens) while the spectral linewidth and weight vary along $(0,0)$-$(\pi,0)$ direction. The other feature $\sim$80 meV, attributed to apical oxygen vibrations, exhibits distinct dispersion toward $(\pi,\pi)$. Such behaviors are observed both above and below the superconducting $T_C$. These detailed measurements provide new insights into the nature of EPC in such materials. * Supported by China NSF-10704084, NSF DMR-0346826, NSF and DOE (NSF-DMR-0451163 and DMS&E).

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